

"TURNING BACK THE CLOCK" ON SERIAL-STIMULUS SIGN TRACKING

ROBERT W. ALLAN AND T. JAMES MATTHEWS

LAFAYETTE COLLEGE AND NEW YORK UNIVERSITY

Two experiments examined the effects of a negative (setback) response contingency on key pecking engendered by a changing light-intensity stimulus clock (ramp stimulus) signaling fixed-time 30-s food deliveries. The response contingency specified that responses would immediately decrease the light-intensity value, and, because food was delivered only after the highest intensity value was presented, would delay food delivery by 1 s for each response. The first experiment examined the acquisition and maintenance of responding for a group trained with the contingency in effect and for a group trained on a response-independent schedule with the ramp stimulus prior to introduction of the contingency. The first group acquired low rates of key pecking, and, after considerable exposure to the contingency, those rates were reduced to low levels. The rates of responding for the second group were reduced very rapidly (within four to five trials) after introduction of the setback contingency. For both groups, rates of responding increased for all but 1 bird when the contingency was removed. A second experiment compared the separate effects of each part of the response contingency. One group was exposed only to the stimulus setback (stimulus only), and a second group was exposed only to the delay of the reinforcer (delay only). The stimulus-only group's rates of responding were immediately reduced to moderate levels, but for most of the birds, these rates recovered quickly when the contingency was removed. The delay-only group's rates decreased after several trials, to very low levels, and recovery of responding took several sessions once the contingency was removed. The results suggest that (a) sign-tracking behavior elicited by an added clock stimulus may be reduced rapidly and persistently when a setback contingency is imposed, and (b) the success of the contingency is due both to response-dependent stimulus change and response-dependent alterations in the frequency of food delivery. The operation of the contingency is compared with the effects of secondary reinforcement and punishment procedures.

Key words: autoshaping, sign tracking, omission training, negative automaintenance, serial stimuli, operant-response interactions, key peck, pigeons

Several researchers have demonstrated the power of an added clock stimulus in the control of the temporal distribution of operant key pecking in fixed-interval schedules (Auge, 1977; Ferster & Skinner, 1957; Ricci, 1973). In fact, Ferster and Skinner (1957) suggested that added clock stimuli may come to control this distribution much more effectively than the organism's behavior (p. 12). In other words, in the added clock preparation, exteroceptive stimuli seem to be more effective than interoceptive stimuli at controlling behavior distributions.

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In addition, other researchers (Matthews & Lerer, 1987; Palya, 1985) have demonstrated powerful control of response distributions in fixed-time (FT) schedules with an added clock stimulus. During these schedules, sign tracking was reliably generated and maintained, and other categories of adjunctive responding (e.g., locomotion) became similarly organized with respect to the clock stimulus. For example, Matthews and Lerer (1987) exposed pigeons to a response-independent schedule with an added clock stimulus composed of a "ramp" of increasing light intensities illuminating a response key. Each series of changing light intensity was followed by food delivery. After many presentations of this ramp stimulus, all of the birds began pecking the response key (autoshaped key pecking) as the light intensity achieved its highest values during the last half of the interfood interval (IFI). Three types of probe trials evinced the strength of the associative control exerted by this added clock stimulus: (a) A continuous bright light

maintained high rates of responding throughout the IFI, (b) a continuous dim probe maintained near-zero rates, and (c) a decreasing ramp series (comparable to running the clock backwards) reversed the distribution of key-peck responses with key-pecking rates decreasing as the signal light intensity decreased. Matthews and Lerer (1987) concluded that the responding recorded in these treatments was largely a function of a Pavlovian process in which the changing, predictive light intensities exerted control over the distribution of elicited responding.

It is of considerable interest to examine the effects of imposing a response-reinforcer (operant) suppressive contingency on the key pecking generated under ramp-stimulus conditions. In the past, this type of contingency has served as the standard method of determining the operant or Pavlovian character of the schedule-elicited responses (Williams & Williams, 1969).

The contingency design reported here was based on the work of Hursh, Navarick, and Fantino (1974) in which a trial offset delay (TOD) was contingent on key pecking. In their procedure, each response delayed the offset of the trial stimulus by some set duration, and the trial could be extended indefinitely if the pigeon continued to peck the keylight. However, the design of the present contingency differed in that, unlike the discrete trial procedure of Hursh et al. (1974), the stimulus in the present experiment (see Matthews & Lerer, 1987) was always present at some brightness level. Also, the present design took advantage of the continuous incremental nature of the ramp stimulus (because the manipulation of light intensity has proven to be a factor critical to the formation and maintenance of distributed responding). A setback contingency was constructed such that increases of light intensity occurred only in the absence of key pecking, whereas pecks resulted in two programmed effects: (a) an immediate setback to the previous intensity value, and, because food was delivered only after presentation of the highest light intensity, (b) a consequent delay (setback) of the next food delivery.

Like the TOD procedure, this design permitted the indefinite extension of the duration of individual trials, but unlike the TOD procedure, which altered the signal value of the discrete stimulus relative to the intertrial in-

terval (Gibbon & Balsam, 1981), the present design allowed the incremental stimulus to continue to serve as a reliable predictor of food delivery. When the bird's responding was reduced, the incremental stimulus continued to increase to its highest value, at which point food was delivered. Although reinforcement could be delayed, the value of the incremental stimulus continued to accurately predict the time to the next food delivery, given that no further responding occurred.

EXPERIMENT 1

Williams and Williams (1969) reported that pigeons would still acquire autoshaped key-peck responding when pecks resulted in the termination of the trial stimulus and cancellation of the food delivery. For this reason, the first experiment examined the acquisition of sign tracking to an incremental keylight stimulus in groups of birds studied with and without the setback contingency in effect. After all birds were exposed to the contingency, a non-contingent phase was employed to examine sustained effects of the setback procedure.

During all phases of the experiment both pecking and activity rates (as defined by floor-board panel closures) were monitored. This was done so that the selective effect of the response contingency might be measured with respect to a separate class of responding that had no contingent effect.

METHOD

Subjects

Eight naive White Carneau pigeons obtained from the Palmetto Pigeon Plant were food deprived and maintained at 80% of their free-feeding weights, receiving almost all of their daily food intake during experimental sessions. In the home cage, under a 12:12 hr light/dark cycle, all birds had free access to water and grit.

Apparatus

The experimental chamber measured 73 cm long, 38 cm wide, and 41 cm high, and housed a Grason-Stadler pigeon intelligence panel. The panel was equipped with a keylight positioned 20.5 cm from the floor of the chamber and centered above a food aperture (4.5 cm by 5 cm). This food opening was 7 cm from the

floor of the chamber; both keylight and hopper apertures were centered horizontally on the intelligence panel.

The keylight stimulus was a light source (1.5 cm square) made from five yellow light-emitting diode bars (HLMP-2450) that were mounted behind the response key (2 cm diameter). The stimulus intensity was varied by a pulse-width modulation technique. A Plessey Micro-I® computer generated a 60-Hz train of pulses that varied in duration from 0 ms to nearly 17 ms. Using 30 values derived from an increasing logarithmic function of pulse widths and assigning one value to each second of the 30-s trial allowed the presentation of a stimulus light that appeared brighter as each second of the trial interval elapsed. Pecks that successfully opened the normally closed key contacts were recorded by the computer and also stepped the pen on a cumulative recorder (Gerbrands, Model C-3).

The floor of the experimental chamber was made up of nine rectangular acrylic panels (16.2 cm by 12.1 cm by 0.3 cm), each mounted on four microswitches positioned at the corners of the panels (for a more detailed description, see Matthews & Lerer, 1987). When a bird stepped on a panel, closing one or more of the microswitches, the computer read and stored this event as an activity response.

The top of the experimental chamber was transparent acrylic; this allowed video monitoring of the pigeons during the experiment. The chamber was housed in an Industrial Acoustics sound-attenuating chamber that was illuminated by a 60-W lamp mounted 91.5 cm above the experimental chamber. The interfacing, computer, and video monitoring equipment were located in a room adjacent to the sound-attenuating chamber.

Procedure

Hopper training. In the initial session, a small amount of mixed grain was scattered in front of the hopper aperture. As soon as the pigeon began eating the grain, a 40-trial hopper training session was started, during which the hopper was raised for 3 s on a variable-time (VT) 30-s schedule. Two training sessions were conducted for each bird, and by the end of the second session all birds were eating from the hopper.

Group 1. Four of the birds (18, 19, 24, 25) were then exposed to 15 sessions of an FT 30-s

schedule with the added ramp stimulus (because of the presence of the ever-changing ramp stimulus, each FT 30-s interval is hereafter referred to as a trial). In this condition, regardless of whether key pecking occurred, the keylight brightness increased each second for 30 s and the trial terminated with a 3-s hopper presentation accompanied by a darkened key (Figure 1A).

For the next 15 sessions, these birds were exposed to a setback procedure, which specified that for each key-peck response the keylight intensity was immediately decreased by one intensity value (Figure 1B). Each peck also effectively reset a 1-s timer. Only after 1 s without a peck did the intensity of the keylight again increase. If pecking persisted, the behavior could succeed in driving the keylight intensity to the value presented at the start of the trial. Key pecks in the presence of the starting value did not further reduce the intensity of the stimulus but did delay the reinforcer by 1 s for each key peck. There were no programmed consequences for key pecks that occurred simultaneously with hopper activation.

Finally, for five sessions, these birds were returned to the FT 30-s conditions without the setback contingency in effect. All sessions in all conditions consisted of 45 trials.

Group 2. After hopper training, Birds 1, 2, 13, and 14 were initially exposed to the setback contingency for 53 days. On Day 54 the contingency was removed, thereby exposing the pigeons to response-independent 30-s ramp stimulus presentations followed by 3-s hopper deliveries. This phase continued for 15 sessions of 45 trials each.

RESULTS

Group 1. Figure 2 depicts, for each bird in Group 1, mean key-pecking and activity response rates (responses per second) per session. By the third session under the FT 30-s schedule, all pigeons were key pecking. These rates increased, reaching asymptote between 0.5 and 1.25 responses per second prior to the introduction of the setback contingency. When the contingency was introduced, key-pecking rates dropped abruptly for all birds and, after the 2nd day, were maintained at near-zero levels until the contingency was removed during the last five sessions. During this final phase, rates of pecking increased immediately for 3 pi-

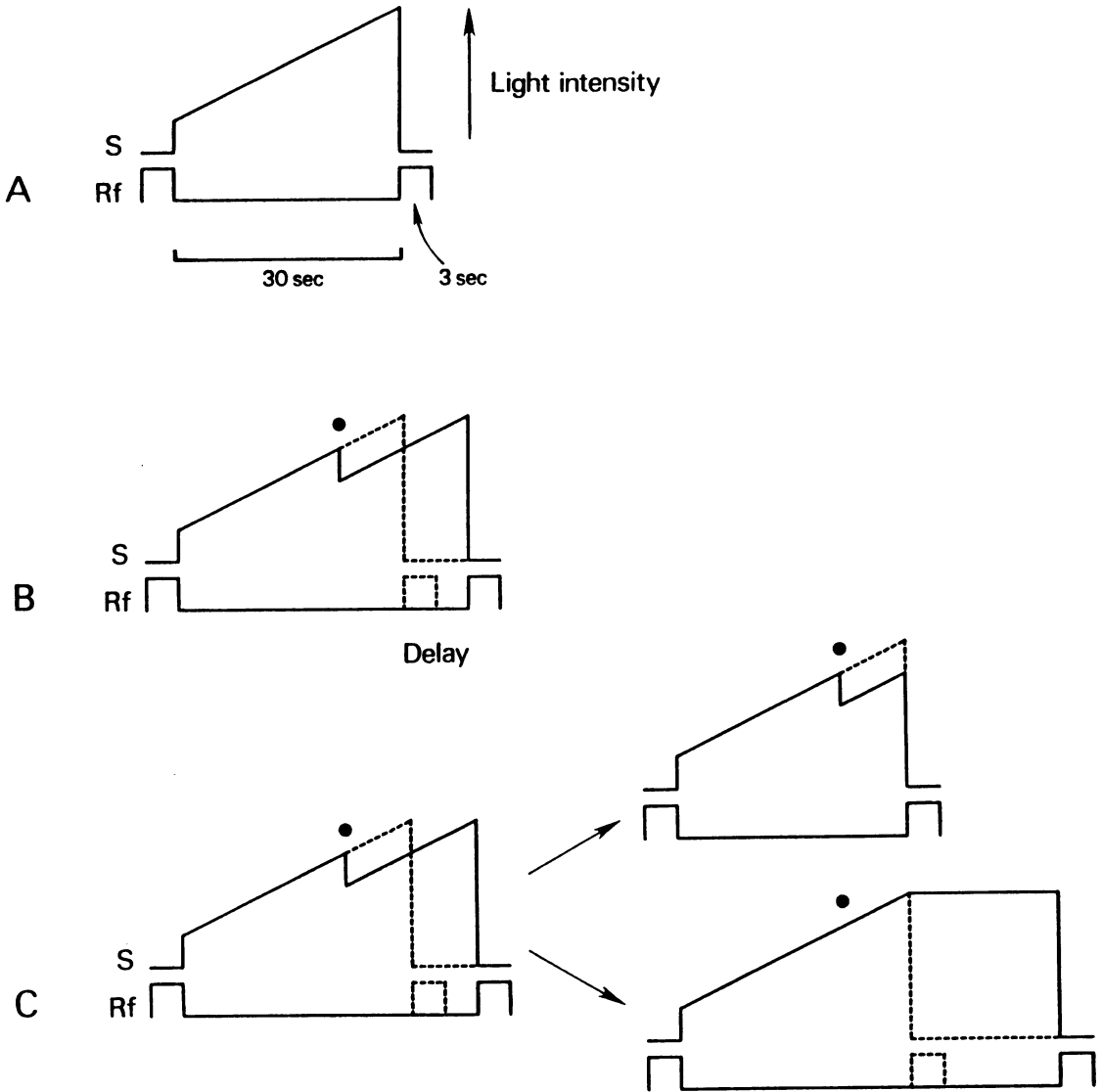


Fig. 1. (A) Changes in light intensity during noncontingent interfood intervals. (B) An example of how light-intensity changes and food deliveries are delayed during the setback procedure, with the filled circle indicating the temporal location of a bout of key pecking. (C) The stimulus change and food-delivery delay associated with the stimulus-only (above) and delay-only (below) conditions.

geons. Bird 24's rate of pecking increased, but did not reach its former level of approximately 0.5 responses per second. Key-pecking rates for Bird 25 remained low, and, although not portrayed in Figure 2, this pigeon was studied for an additional 10 days (15 days total) with the setback contingency removed. Observed rates of responding never exceeded 0.04 responses per second.

Activity rates for all subjects were variable,

but, in general, did not seem to change systematically as a function of the contingent reduction in key pecking. There was no evidence of a complementary increase in activity responding as key-pecking rates decreased. Bird 18's rate of movement, along with key pecking, decreased for the first three setback sessions; however, this subject's Phase 1 rates of movement were quite variable (see Sessions 11 and 12).

Group 2. Figure 3 shows, for each bird in Group 2, mean key-pecking and activity response rates (responses per second) per session. By the fifth session, with the setback contingency in effect, all birds were key pecking. Pecking rates did not reach as high a level nor were they reduced (once key pecking began) as quickly and thoroughly as those observed in the setback phase for Group 1. The overall trend for Birds 1, 2, and 14 was a decline in key pecking over the 53 sessions of exposure to the setback contingency; however, the rate of decline differed for each bird.

Bird 1 began key pecking during the second session. Rates increased during Sessions 3 and 4, achieving a rate of approximately 0.34 responses per second. On Day 5 the rate of key pecking fell to 0.15 responses per second and stayed at approximately that level until Session 34, after which responding fell to near-zero levels.

Bird 2 also began key pecking during the second session and rates increased to 0.32 responses per second during Session 9. After Session 29, rates of key pecking stayed below 0.14 per second for the remainder of the setback phase.

Bird 13 did not key peck until Session 5, achieving a peak rate of approximately 0.21 responses per second on Day 8. After that session, rates of responding became stable at approximately 0.125 responses per second and rarely exceeded 0.15 responses per second through the end of the setback phase.

After beginning to key peck on Day 3, Bird 14 pecked at a maximum of 0.28 responses per second on Day 6. Rates of responding declined thereafter, reaching near-zero levels after Session 43.

All of the birds in Group 2 began key pecking at higher rates when the setback contingency was removed during the final phase of the experiment. Birds 2 and 14 showed the most rapid and sustained increases in pecking. For Bird 1, keypecking increased slowly over the 15 days of exposure to the FT 30-s schedule; Bird 13's rate increased only from 0.18 to 0.24 responses per second.

Although key pecking developed for all birds in Group 2, key-peck response rates were consistently lower than those observed for Group 1 during the noncontingent phase of the experiment.

In general, the activity rates for Group 2

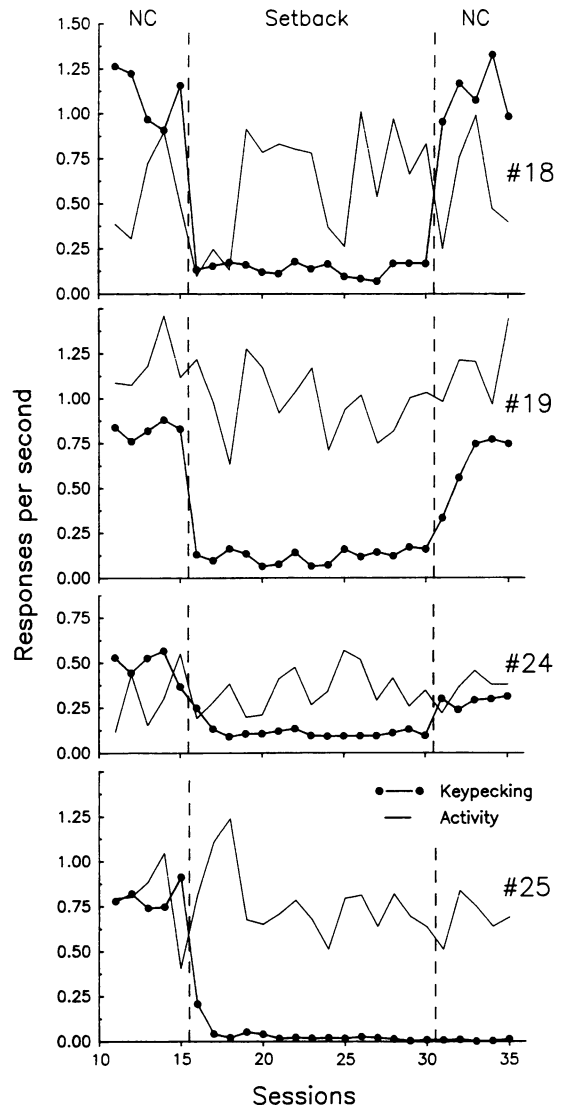


Fig. 2. Key-pecking and activity rates (per second) by session for individual birds in Group 1 who had prior noncontingent (NC) training with the ramp stimulus. Rates from the last 5 days of training, 15 days of the setback contingency, and 5 days after removal of the contingency are depicted. Bird numbers are indicated at the right of each plot.

subjects did not change systematically as a function of changes in the rate of key pecking. Subject 1's movement levels seemed to increase steadily, even after the contingency was removed and key pecking increased.

For Bird 2, there was evidence that the rate of movement tracked the rate of key pecking (see Sessions 18 through 33). Near the end of

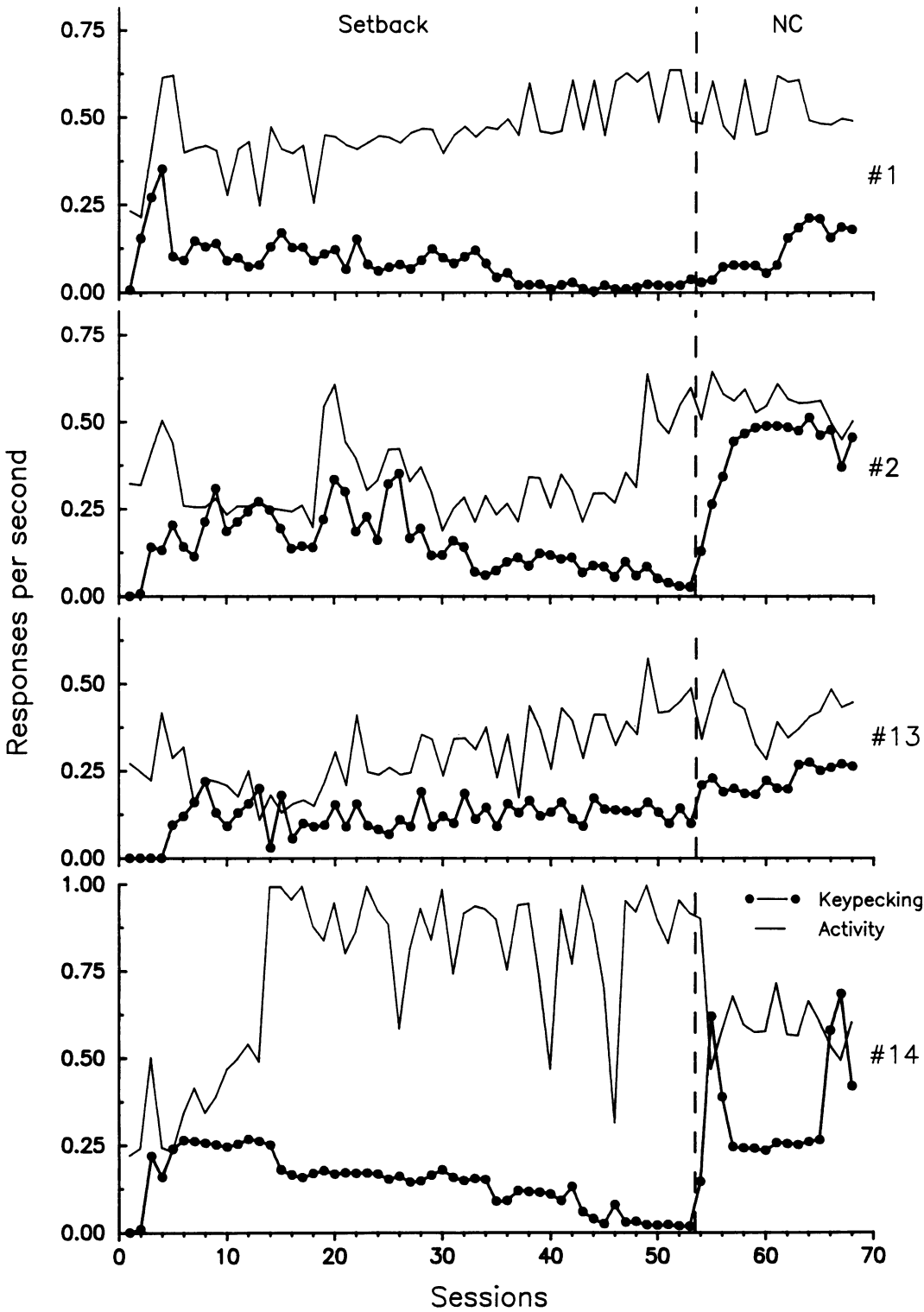


Fig. 3. Key-pecking and activity rates (per second) by session for individual birds in Group 2 who were exposed to the setback contingency from the beginning of training. Bird numbers are indicated at the right of each plot.

the contingent phase, as key-pecking rates decreased to near-zero levels, rates of movement started to increase; however, that pattern of increase continued even after removal of the contingency with its attendant increase in key pecking.

Bird 13's movement rates also increased steadily during the contingent phase, but showed no evidence of decrease once key pecking increased after removal of the contingency.

Bird 14's response patterns are somewhat consistent with a potential trading relation between key pecking and activity. During Session 15, there was a drop in key pecking, with an attendant dramatic increase in activity rates. This new level of movement remained somewhat stable until the contingency was removed; then, activity rates decreased as key pecking increased.

DISCUSSION

These results, first of all, confirm Matthews and Lerer's (1987) observation that an incremental ramp stimulus added to an FT schedule of reinforcement is sufficient to generate significant rates of autoshaped key pecking. This confirmation is seen most clearly in the rates of responding established under the FT 30-s schedule (Group 1), which became stable between 0.38 and 1.26 responses per second.

The analysis of the effects of the setback contingency suggest that (a) the contingency abruptly and thoroughly reduced the frequency of sign-tracking behavior (key pecking) when introduced after response-independent schedule training; (b) when the setback contingency was in effect during the acquisition phase, key pecking was still engendered, but at lower rates; (c) when the contingency was in effect during acquisition, extended exposure led to a reduction of key pecking below peak levels observed early in training for 3 of the 4 pigeons; (d) response rates generally increased when the contingency was lifted; and (e) the effect of the contingency was selective, in that only the rate of the targeted response (key pecking) was reduced; activity responding was not systematically altered during the contingent conditions.

The acquisition of key pecking when the setback contingency was imposed during training (Group 2) seems to imply that the Pavlovian power of the ramp stimulus in eliciting key pecking was initially dominant over the

operant setback contingency. This interpretation, however, is weakened by the observation that the setback contingency was actually more effective following a response-independent acquisition phase with the added ramp stimulus, a condition that would be expected to strengthen rather than diminish the relative influence of the Pavlovian conditioned stimuli.

An alternative interpretation of the persistent responding observed in pigeons initially exposed to the setback contingency suggests that when presented simultaneously, the Pavlovian and operant contingencies are mutually degrading in a dynamic fashion. Early in training, before key pecking develops, the ramp stimulus is presented on many trials before responding begins, and, therefore, there is no interference from the setback contingency. The first responses, however, result in a disturbance of the ramp stimulus sequence and a lengthening of the IFI. These disturbances occur at a point in the conditioning process at which the incremental stimuli are just beginning to functionally elicit responding and, presumably, at a time when putative conditioned reinforcing and/or conditioned punishing properties of the stimuli may be developing (Auge, 1977). Response-produced degradation of the signal will, in turn, reduce the conditioned reinforcing or punishing capability of stimulus intensity changes. Once responding is initiated on this schedule, delays of reinforcement are introduced that may contribute to the degradation of the control of the ramp stimulus. All of this may result in a decrease in rate of responding that then leads to a restoration of the predictive power of the stimulus sequence and further response elicitation. This process may result in a waxing and waning of elicited responding for many trials over many sessions.

With one exception, the overall results correspond with those observed in comparable manipulations with discrete-trial omission training (e.g., negative automaintenance; Williams & Williams, 1969), TOD (Hursh et al., 1974), and differential-reinforcement-of-other-behavior (DRO) schedules (e.g., Nevin, 1968). The exception concerns the power of the contingency. It appears that the setback contingency reduced responding more quickly than other procedures used to reduce the frequency of elicited key pecks. This comparison is strained by the dissimilarity of the response

measures (response rate used here; probability of at least one response per trial used elsewhere: e.g., Barrera, 1974) and by the dissimilarity of the trial stimulus (continuous used here, see also Gibbon, Locurto, & Terrace, 1975; discrete used elsewhere: e.g., Williams & Williams, 1969). Nevertheless, it is possible with the setback procedure to reduce response rates from high levels to very low levels within only a few trials, although the first few trials may last as long as 10 min. Furthermore, the relatively unchanged activity measures suggest that the setback contingency, when applied to key pecking, was selective in its effects.

There are several aspects of the setback contingency that may contribute to its efficacy. The two most obvious are (a) the stimulus setback that is immediately consequent upon the response, and (b) the reinforcer delay that is initiated following the 30-s IFI (cf. Dews, 1962). These factors were assessed separately in Experiment 2.

EXPERIMENT 2

This experiment attempted to assess separately the contributions of the response-contingent stimulus-change consequences and the delay-of-reinforcement consequences by exposing pigeons to either one or the other of the component contingencies. For the first group, key pecks reduced the light intensity without delaying the reinforcer, whereas for the second group, responses delayed the reinforcer without changing keylight intensity. Activity responding was not monitored in this experiment.

METHOD

Subjects and Apparatus

Eight naive White Carneau pigeons obtained from Palmetto Pigeon Plant were food deprived and maintained at 80% of their free-feeding weights, receiving almost all of their daily food intake during experimental sessions. Home-cage feeding regimens, lighting conditions, and experimental equipment were identical to those in Experiment 1.

Procedure

These pigeons were all hopper trained as in Experiment 1. All of the birds were subsequently exposed to 15 sessions of an FT 30-s schedule with the added ramp stimulus. On

Day 16, the pigeons were divided into two groups. The stimulus-only group (Birds 27, 28, 29, and 30) was exposed to a modified setback contingency that presented decreases in stimulus intensity contingent on key pecking, but that left the density of reinforcement unchanged. Consequently, pecks disturbed the predictive ramp stimulus sequence, but food deliveries occurred every 30 s regardless of the state of the stimulus light (see Figure 1C).

The delay-only group (Birds 8, 9, 10, and 11) was exposed to response-contingent delay of the reinforcer without the immediate changes in the intensity value of the keylight. If pecks occurred during the IFI, the keylight intensity continued to change undisturbed until the highest intensity was presented. At that point, depending on the number of key pecks produced during the IFI, the trial was extended 1 s for each key peck that occurred during the trial (Figure 1C). Each peck that occurred during the added delay interval, while the stimulus light was at its highest intensity, also extended the interval by 1 s.

During the final 5 days of the experiment, all birds were returned to the initial FT 30-s conditions. The ramp stimulus sequence was unaffected by key-peck responses, and, for the delay-only group, food deliveries once again occurred every 30 s.

RESULTS

Stimulus-Only Group

Figure 4A presents the mean response rates (responses per second) per session for the birds exposed to the stimulus-only contingency. By the fourth session, all birds' rates reached between 0.52 and 1.26 responses per second. When the contingency was introduced, responding decreased for all birds during the first session. In subsequent sessions, rates were kept at low levels until the contingency was removed during the last five sessions. Birds 27, 28, and 29 all began responding at higher rates during the first session with the contingency removed, whereas Bird 30, whose response rate declined throughout the stimulus-only phase, never emitted response rates higher than 0.27 responses per second.

Selected cumulative records for the stimulus-only subjects are presented in Figure 5. The pigeons' individual response patterns were quite similar. Each bird continued to respond on almost every trial, but at lower local rates

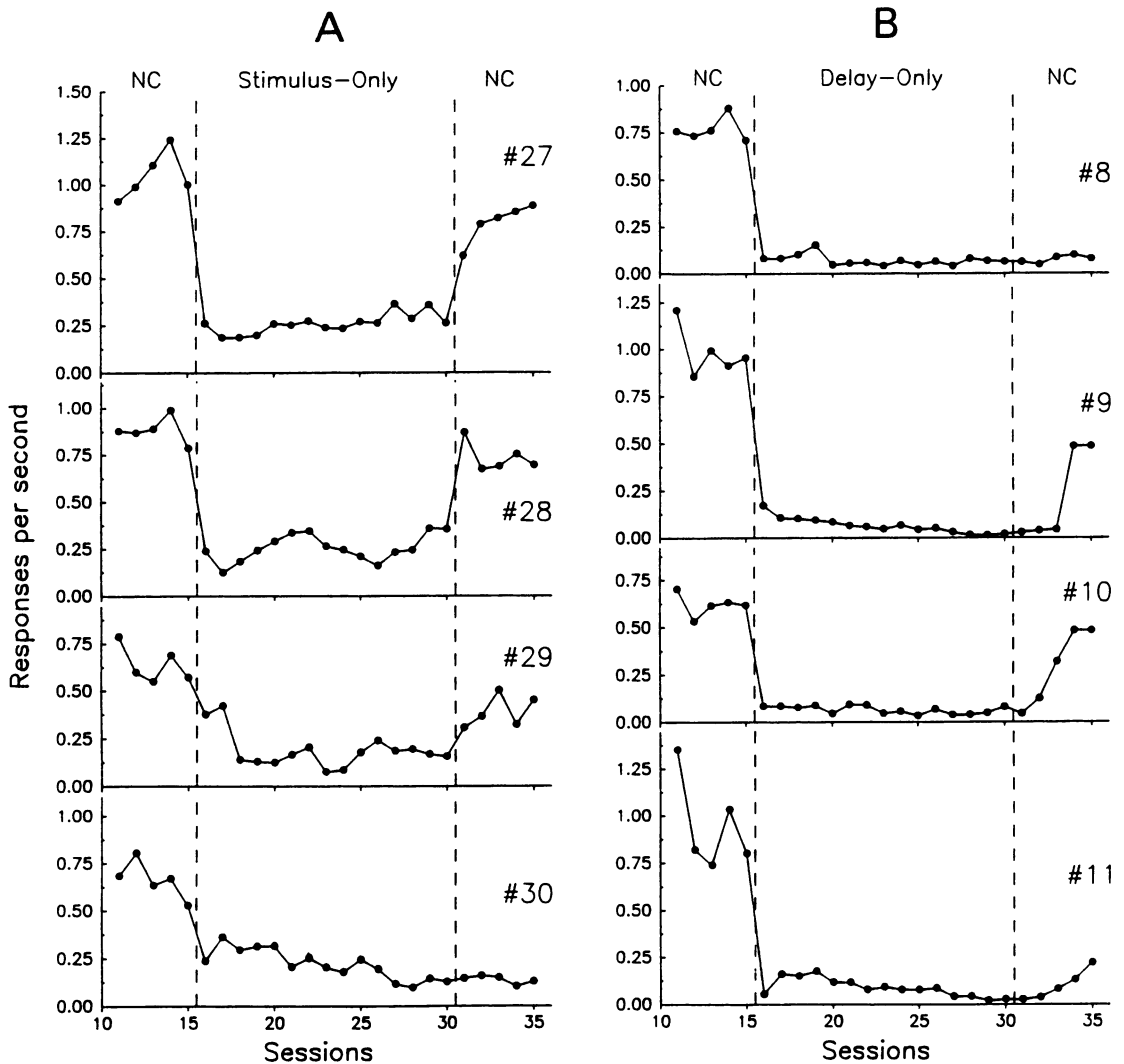


Fig. 4. (A) Rates of key pecking (per second) by session for individual birds in the stimulus-only condition in which key pecking disrupted the ramp stimulus sequence while reinforcers continued to be delivered every 30 s. (B) Rates of key pecking for birds in the delay-only condition. For both groups of plots, five sessions of noncontingent training, all 15 sessions of contingency exposure, and five sessions after removal of the contingency are plotted. Bird numbers are indicated at the right of each plot.

(as compared to the training phase), with Bird 29 showing the only lengthy bursts of responding (in the middle of the second stimulus-only session record) after the contingency was put into effect.

In the final recovery phase, all but 1 of the pigeons (30) began, almost immediately, pecking at rates similar to those observed during noncontingent training. Bird 30's response rates became stable at low levels and showed no sign of recovery.

Delay-Only Group

The mean response rates (responses per second) per session for the birds of the delay-only group are presented in Figure 4B. After 3 days of training, all of the birds were pecking at rates between 0.51 and 1.36 responses per second. When the delay-only contingency was introduced, each bird's rate of responding dropped to near-zero levels during the first session. The rates remained low until the con-

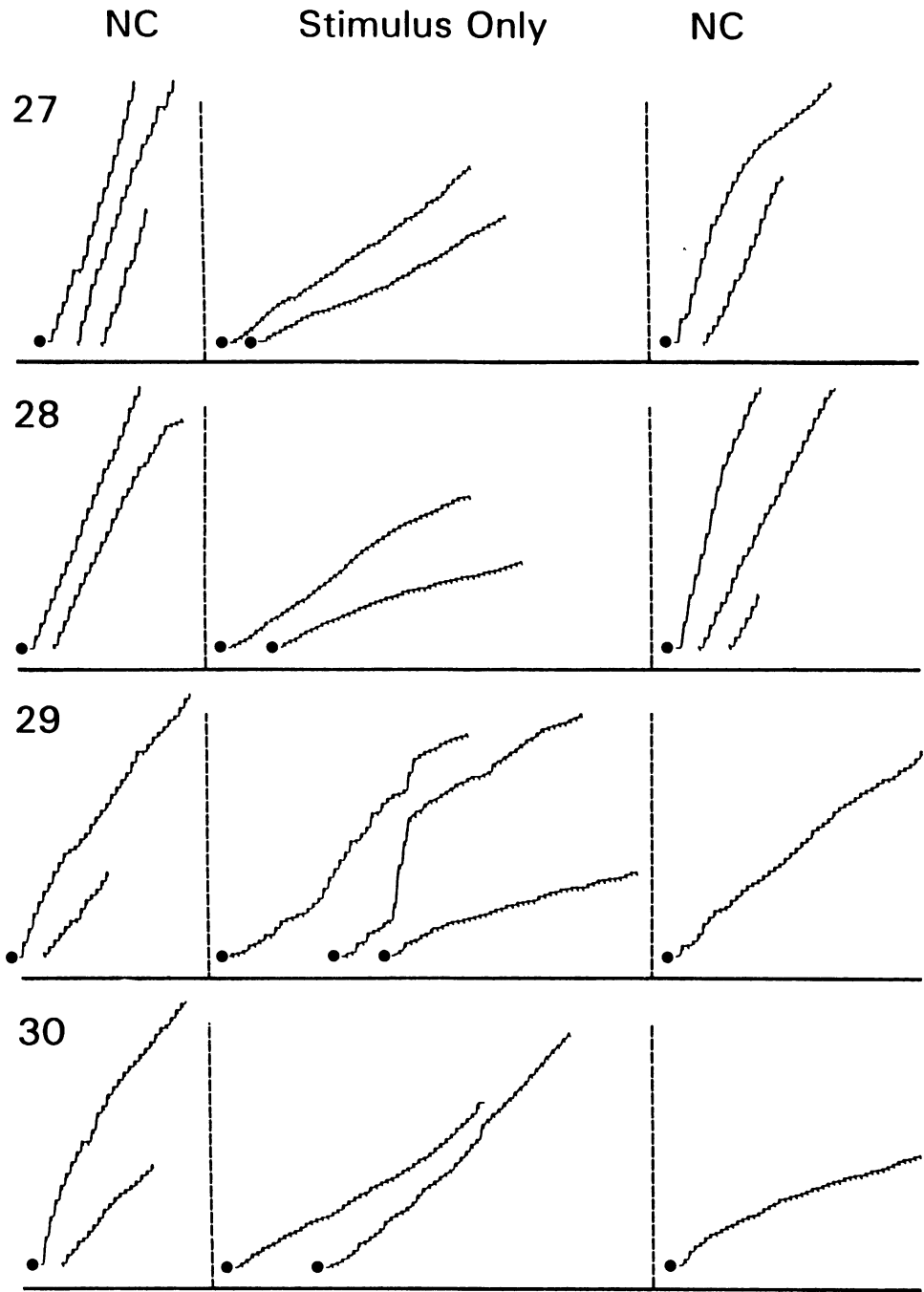


Fig. 5. Selected cumulative records from birds in the stimulus-only group. Vertical dashed lines indicate phase changes, and filled circles mark the beginning of individual sessions; these should be read in sequence from left to right and top down. During the first NC phase, the records are drawn from Session 15. The stimulus-only records represent performance during the first two or three sessions after the contingency was introduced. The records from the final NC phase represent performance during Session 31.

tingency was removed; however, unlike any other birds in any other condition, none of the delay-only subjects began responding at higher rates on the 1st day after contingency removal. In fact, only Subjects 9 and 10 began responding at rates that approximated precontingency levels, and those rates were not achieved until the contingency had been removed for 4 days.

The local response-rate changes can be seen clearly in the individual-subject cumulative records presented in Figure 6. Each bird in the delay-only group began the first trial of the delay-only contingency with no responding. At a point roughly halfway into the trial, each pigeon began pecking at a rate matching those seen during noncontingent training conditions. Because key pecking had no effect on the stimulus intensity sequence, all birds continued to peck at high rates to the end of the highest stimulus intensity value. However, responding functioned to extend the duration of this highest intensity value, and with its extension came continued high rates of responding in all birds. The first trials were lengthened in this way from 30 s to 8 min for Bird 8, 7 min for Bird 9, and approximately 5 min for both Birds 10 and 11. Over the next few trials, individual response rates waxed and waned, but trial durations never exceeded 2.5 min. By the second session, responding for all subjects was reduced to levels yielding averages below four responses per trial (compared to 20 to 30 responses per trial before the contingency was imposed). It seems that most of the contingent control over the probability of responding was achieved during the first few trials of the first session of contingency imposition.

When the contingency was lifted, rates of responding for all birds remained low for the first two to three sessions, with only 0.5 to 2 responses produced on each trial. Bird 8's rates remained low for all 5 days (no recovery), and Bird 9's rates remained low for 3 days, and when they did increase, they never attained precontingency levels. In addition, the grain of Bird 9's response pattern was ragged, with several trials containing no responding. The form of these records contrasts sharply with records generated during the precontingency phase, in which the form is highly stereotyped and regular. Bird 10's rates grew gradually, eventually (by the fourth and fifth postcontingency sessions) achieving rates just below those observed during the precontingency phase. Fi-

nally, Bird 11's rates increased gradually over the five recovery sessions but never approached the precontingency levels.

Although overall session rates for these birds did not recover to precontingency levels, Birds 9, 10, and 11 all produced, on individual trials, local rates similar to those observed before the contingency was imposed.

Group Similarities and Differences

Both contingencies (stimulus only and delay only) decreased response rates rapidly and held responding at low levels until the respective contingencies were removed. However, the session means do not provide sufficient detail on the course of response reduction. The cumulative records suggest that the stimulus-only group's response rates came under rapid control, but all pigeons continued to respond on each trial. The delay-only group's responding continued for 5 to 8 min before the delay contingency took effect, but at that point responding was almost completely eliminated.

Data from the final phase suggest much slower response recovery for the subjects in the delay-only group, and the cumulative records point to the local character of recovery. For 3 of 4 stimulus-only subjects, the process was almost immediate (within the first trial); for the delay-only subjects, the process took several sessions.

Comparison to the Setback Procedure:

Group 1, Experiment 1

Figure 7 presents cumulative records from Group 1 in Experiment 1 whose training and contingency introduction parameters were similar to the stimulus-only and delay-only groups and whose response rates were reduced by the combination of the two component contingencies used in Experiment 2. These records are presented to indicate that for all birds performing under the combined contingency (setback), responding was reduced rapidly (as in the stimulus-only group) and to very low levels (as in the delay-only group). In addition, recovery of responding for the setback group occurred during the first session of contingency removal.

DISCUSSION

It is apparent that both contingent changes in reinforcement density and contingent changes in the stimulus intensity are necessary

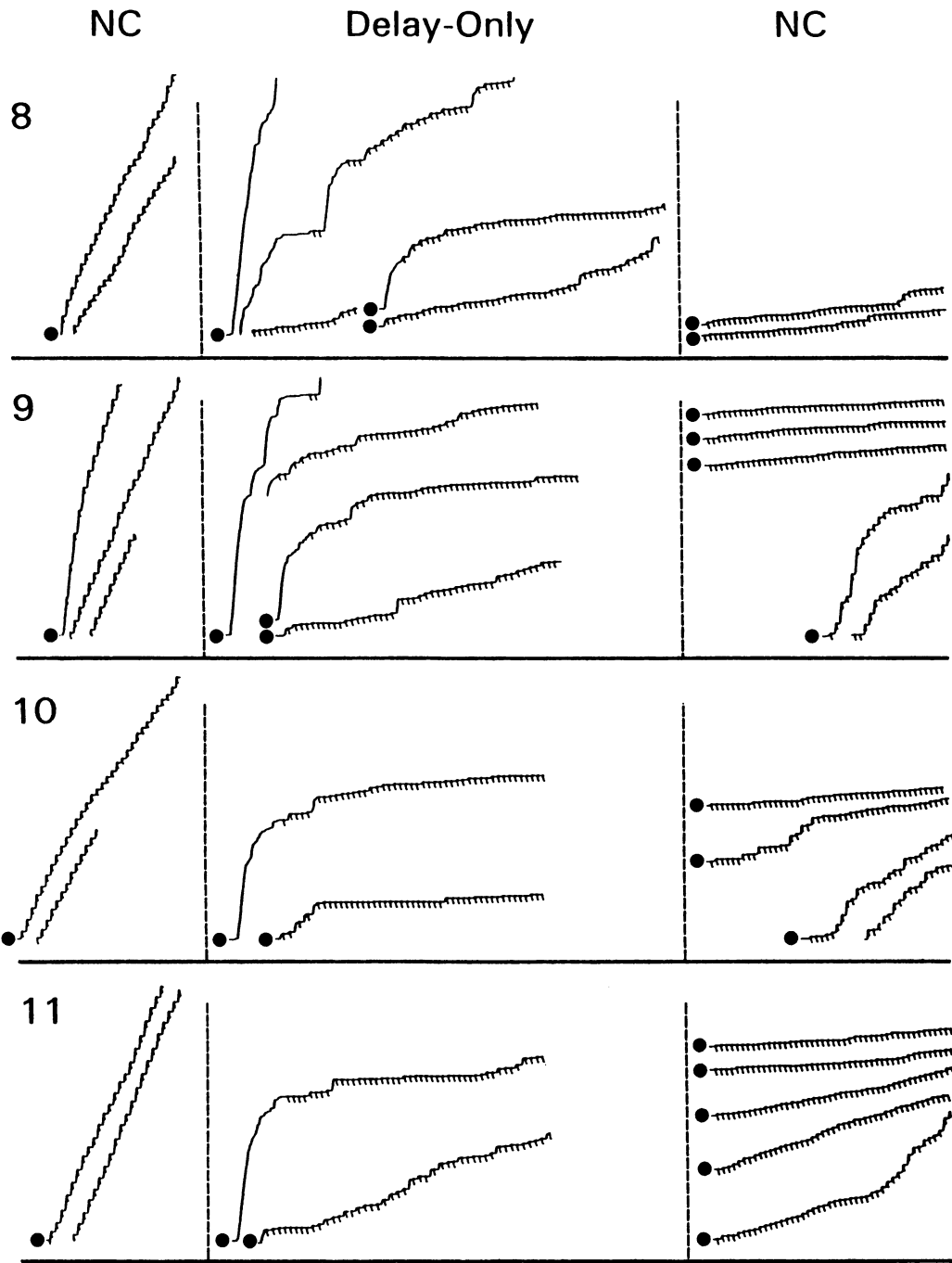


Fig. 6. Selected cumulative records from birds in the delay-only group. The records for the first NC phase are taken from Session 15. The delay-only records are from the first two or three sessions after contingency introduction. The final NC records come from the first two to five sessions of that phase.

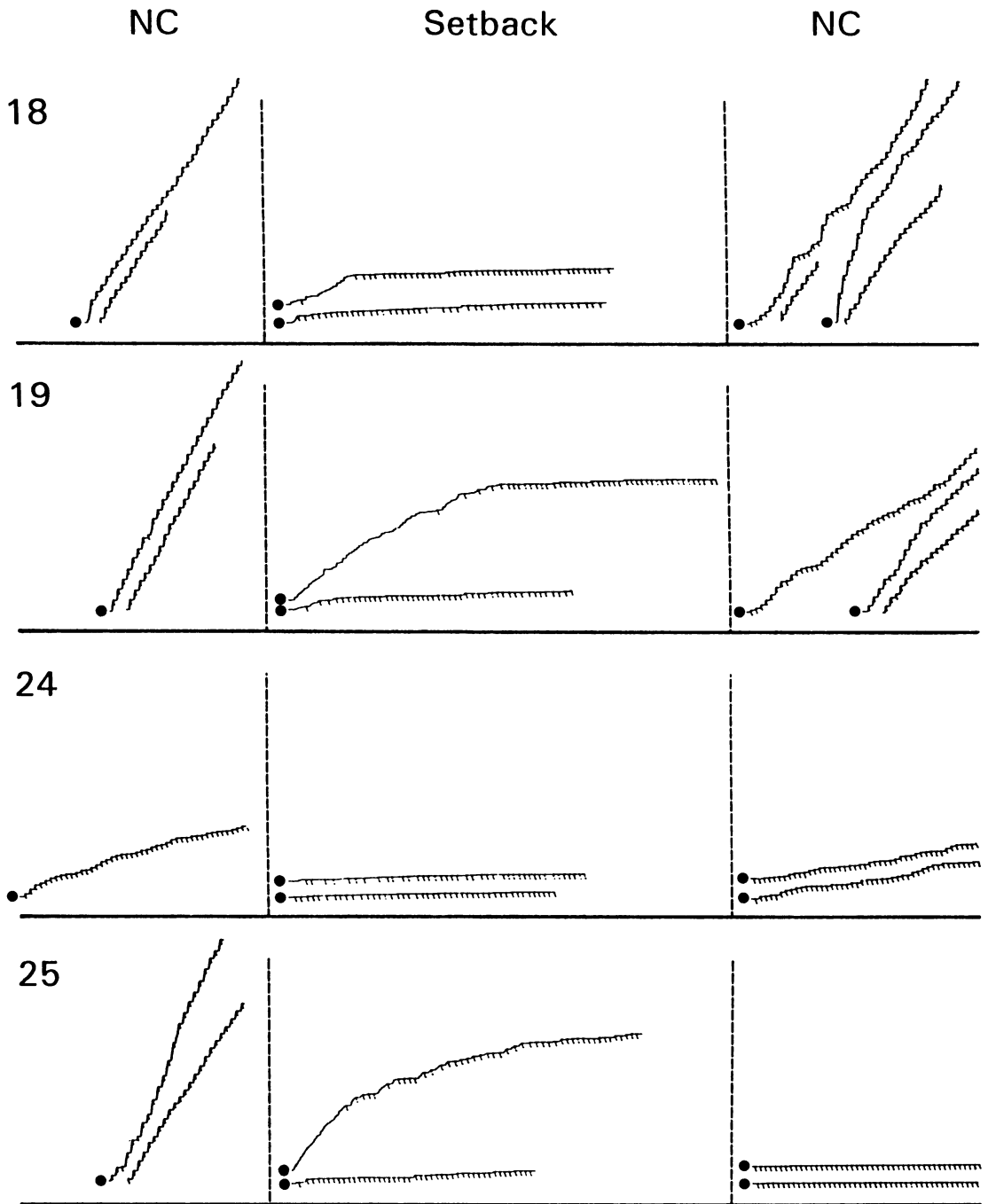


Fig. 7. Selected cumulative records from birds in Group 1, Experiment 1. The records for the first NC phase are taken from Session 15. The setback records are from the first two sessions after contingency introduction. The final NC records come from the first two sessions of that phase.

to reproduce completely the effects of the setback contingency observed for Group 1 in Experiment 1. In contrast to the performance of Group 1 in Experiment 1, the delay-only group maintained much higher rates during the first few trials (see Figure 7). Clearly, this difference derives from the lack of immediate stimulus feedback for key contacts. Because the initial rapid response reduction associated with the setback contingency was seen only in the stimulus-only group, it follows that early suppression is most likely the result of response-contingent changes in stimulus intensity (see Herrnstein & Loveland, 1972; Hursh et al., 1974). The enduringly thorough response reduction produced by the setback contingency appeared only in the delay-only group, indicating that this aspect of response reduction derives from the response-contingent reinforcer delay.

An interesting finding is that stimulus-only birds continued to respond, although at attenuated rates, during the response-contingent conditions. Only on rare trials did the series of keylight intensities proceed, without interruption, to the highest values before reinforcement occurred. It appears that the predictive relationship between keylight intensity and reinforcer delivery sufficient for the establishment of autoshaped key pecking is not a condition necessary for its maintenance. The evidence indicates that even a degraded stimulus series that offers only limited predictive value relative to reinforcer delivery (especially during the last half of the stimulus sequence, when pigeons are most likely to peck; Matthews & Lerer, 1987) is sufficient to maintain responding at moderate levels. In addition, because the contingency did not provide for delays of food delivery, there was ample opportunity for adventitious reinforcement of key pecks even in the presence of a disrupted stimulus.

The rapid reduction of responding during the early trials of the first session for the stimulus-only group is easily interpreted as a case of punishment of key pecking by the contingent presentation of a stimulus value associated with earlier portions of the trial (Auge, 1977; Segal, 1962). This putative punishing factor was missing in the treatment for the delay-only group, resulting in relatively slow response reduction. Another reason for the delay-only group's slow response reduction may be that

the delays were filled with the continuous presentation of the brightest stimulus in the ramp series; the stimulus immediately preceding reinforcement and the stimulus that characteristically elicited some of the highest rates of key pecking (see Matthews & Lerer, 1987). The delay-only condition allowed the stimulus to go to brighter values that, at least until the contingency took effect, were expected to elicit more responding.

This slower response recovery observed in the delay-only group after the return to FT 30-s conditions attests to the controlling function of the response feedback produced during the setback procedure. When response rates were driven to low levels by the delay-only contingency, the pigeons were exposed to the same sequence of stimuli and similar densities of reinforcement presented during initial FT 30-s training. Later, removal of the contingency and return to the FT 30-s schedule functioned to control the return of autoshaped key pecking only if some aspect of the schedule signaled the changed contingencies and if rates of responding were high enough to sample those contingency changes. But the birds' response rates were reduced so thoroughly that there was little, if any, change in the durations of the highest keylight intensity value or the densities of reinforcement between the delay-only and FT 30-s conditions.

The contribution of the two components of the setback contingency to its success in reducing the rate of autoshaped key pecking are well delineated by the results of Experiment 2: (a) Without response-contingent changes in reinforcer density, response-contingent change in stimulus intensity only reduced responding to moderate levels; and (b) without the immediate change in the keylight stimulus, response rates were slowly reduced and, once reduced, took longer to recover.

GENERAL DISCUSSION

The research reported here used rate of responding as a measure of the sensitivity of sign-tracking responses to an operant contingency that effectively "turns back the clock" and used the setback contingency to produce rapid and persistent reduction in the rate of sign-tracking responding. This research suggests that the success of the setback contingency may be due, in part, to the control of response-dependent

stimulus change as well as response-dependent alterations in the frequency of food delivery, and suggests that the effects of the setback contingency are specific to the targeted behavior—rates of a nontargeted response (activity) were not systematically affected by the contingency.

Response rate turned out to be a very sensitive measure of the success of the setback contingency. Many of the birds pecked on a large number of trials during the response-contingent phases. In fact, these rates would have been sufficient, under an omission contingency (which generally requires only a single peck), to cancel many of the reinforcers (see cumulative records). Rate of responding, however, clearly showed the power of this negative response contingency (see also Deich & Wasserman, 1977). Rates were quickly and dramatically suppressed to levels comparable to, if not lower than, rates obtained in aversive punishment designs using "severe" levels of shock (cf. Azrin, 1960; Wesp, Lattal, & Poling, 1977).

Although the setback procedure resembles the TOD design of Hursh et al. (1974), the speed of response reduction differed. Because both procedures involve a delay of reinforcement, an obvious difference is related to the addition of response-contingent stimulus feedback in the present design. Because the ramp stimulus sequence represents a graduated measure of time until reinforcement, and because one of the response consequences is a resetting of this stimulus to a value more remote from reinforcement, it may be expected that small changes in the schedule of food delivery are more apparent when signaled by changes in the ramp stimulus.

The delay-only contingency most closely resembles the TOD procedure of Hursh et al. (1974), in that there is a delay from the last key peck to the offset of the trial stimulus. Both procedures resulted in slower response reduction, and in this respect the schedule effects are similar. In addition, the delay-only contingency suppressed responding to very low levels.

Secondary Reinforcement

Fantino (1977) indicated that "a stimulus correlated with a reduction in time to primary reinforcement should be a conditioned reinforcer, i.e., it should maintain responses—

whether or not these responses affect the temporal distribution of reinforcement" (p. 315). In a molecular sense, the "full" setback contingency (maintaining both stimulus-change and reinforcer-delay components) eliminated superstitious pairings of key pecking and the putative secondarily reinforcing stimuli (the increasing intensity stimulus presentations). The only way that the next stimulus in the series of increasingly powerful secondarily reinforcing stimuli would be presented was if responding did not involve key contact. Although no attempt was made to quantify rates of off-key pecking (Barrera, 1974; Lucas, 1975; Wessells, 1974), this behavior was observed during many of the setback sessions. Accordingly, the present contingency may represent a DRO schedule with secondarily reinforcing stimuli (increasing keylight intensities) serving to strengthen any other responses directed away from the key (Dougan, McSweeney, O'Reilly, & Eacker, 1983).

Secondary Punishment

If stimuli signaling closer proximity to primary reinforcers function as conditioned reinforcers, then perhaps the contingent production of stimuli signaling increased temporal distance to reinforcers might serve as effective secondary punishers (Auge, 1977). In fact, the ramp procedure may enable each stimulus in the ramp to act as a punisher when it contingently replaces a brighter stimulus and to act as a reinforcer when it replaces a dimmer stimulus. It also seems to follow that the power of the punisher may be proportional to the magnitude of the brightness change. Clearly, optimal use of the setback contingency will benefit from the functional analysis of these contingency parameters.

Delay Contingency

In addition to the immediate response-dependent changes in stimulus intensity, the delayed changes in reinforcer density seem to play a role, not only in the successful reduction of responding but also in the measured lag to reacquisition once the contingency is removed. Reinforcement-density changes appear to be a very important factor in the successful suppression of key pecking in this situation. Staddon (1977) has suggested that "Negative contingencies do have some suppressive effect on a response such as pecking . . ." but goes on

to argue that "... much of the effect is attributable to effects of the contingency on the frequency and pattern of food delivery, i.e., on temporal and stimulus (not response) contingencies" (p. 128). The results of the present experiments, however, suggest that changes brought about by this negative contingency (setback) exerted more than some suppressive effect. The recorded response reduction was large, clear, and common to almost all birds in all conditions. In addition, the change in the frequency and pattern of food delivery was sufficient to decrease key pecking but did not systematically alter another response, general activity.

If key pecking recorded in these experiments was not sensitive to contingent effects, then what explanation might be given for continued key-peck reduction even after the stimulus sequence and density of reinforcement returned, essentially, to their original values? During the setback phases, once key pecking was reduced, the stimulus intensity sequence was almost identical to the pattern that engendered high rates of pecking during FT 30-s phases. But high rates of responding did not reemerge until the setback contingency was removed and key pecks no longer affected stimulus or reinforcer-density parameters. Once the contingency was removed, most pigeons almost immediately began pecking at higher rates (but see the delay-only group results). It seems clear that these responses are, in some sense, supported by respondent factors as long as competing operant contingencies are not in effect.

The recovery data of birds in the stimulus-only conditions confirm the importance of the response-stimulus-change contingency in the successful reduction of responding. Most of these pigeons reacquired higher key-pecking rates much more rapidly after removal of the setback contingency than did the birds exposed to the delay-only conditions (see Figures 5 and 6, third phase). During the stimulus-only contingency, responding affected a more conspicuous property of the stimulus-reinforcer relation (the stimulus intensity), and when the contingency was removed, a single key peck without its accompanying intensity diminution immediately set the occasion for more rapid responding.

A final bit of evidence that reinforcer density is not always necessary in the control of response rates is found in the setback results (see

Figure 7, third phase). Response rates for Birds 18 and 19 increased during the *first* trial after removal of the setback contingency, implying local, response-contingent control of rate. Reinforcer density could not have played a role because, during the first trial after return to noncontingent conditions, reinforcers had not yet been delivered. These findings also suggest that many trials contained at least one response, thereby decreasing the utility of *number of trials with at least one response* as a sensitive measure of the strength of the contingencies used in these experiments.

Conclusions

The present study stands as a strong statement of the power of operant contingencies in the control of elicited behavior. These experiments were not designed to confront issues of response provenance, nor did they attempt to investigate the importance of the effects of adventitious reinforcement on response maintenance. Rather, the present work was designed to examine a highly probable response's sensitivity to the effects of response-contingent delay of reinforcement, while an explicit clock stimulus (intensity ramp) maintained a predictive relation to forthcoming reinforcers. The results suggest that response-contingent signaled delays effectively reduce frequently occurring responses. In addition, these responses remain under control (at low rates) until the operant contingency is removed.

Other seemingly intractable responses have been found to be sensitive to negative contingencies. Allan (1984) presented evidence that locomotor behavior occurring during an interfood interval is also sensitive to stimulus setback contingent on floor panel closures (see also the control of imprinted following, Barrett, 1972; Barrett, Hoffman, Stratton, & Newby, 1971; Hoffman, Stratton, & Newby, 1969; and the control of stimulus-bound eating and drinking, Shinkman, 1973¹). Taken together, these and other data suggest that elicited behavior may be effectively controlled by response-contingent feedback and response-produced changes in reinforcer density even though the procedures used to generate responding were Pavlovian in character.

¹ Shinkman, P. G. (1973). *Modification of electrically elicited consummatory behaviors*. Paper presented at the meeting of the Psychonomic Society, St. Louis.

Finally, suppression of elicited behavior is a persistent problem in a variety of behavior management domains. The power of the set-back contingency to suppress behavior without the use of aversive stimuli or the elimination of reinforcers commends it to these behavior management tasks.

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